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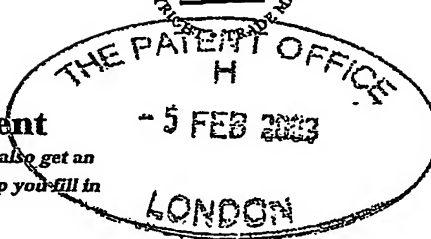
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| 2. Patent application number (The Patent Office will fill in this part) | 05 FEB 2003 | 0302659.8 | |
| 3. Full name, address and postcode of the or of each applicant (underline all surnames) | OCUIY LIMITED 1 Yeffly Drive Oxford OX4 4XS | | |
| Patents ADP number (if you know it) | 08 203622 001 | | |
| If the applicant is a corporate body, give the country/state of its incorporation | GB | | |
| 4. Title of the invention | DISPLAY APPARATUS | | |
| 5. Name of your agent (if you have one) | J.A. KEMP & CO. | | |
| "Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode) | 14 South Square Gray's Inn London WC1R 5JJ | | |
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DISPLAY APPARATUS

The present invention relates to an apparatus for the display of images. Such an apparatus may be used in autostereoscopic three dimensional displays, switchable two dimensional (2D) / three dimensional (3D) autostereoscopic displays and for a switchable high brightness display system. Such systems may be used in computer monitors, telecommunications handsets, digital cameras, laptop and desktop computers, games apparatuses, automotive and other mobile display applications as well as telecommunications switching applications.

Display systems which use micro-optic components in order to enhance their functionality include Liquid Crystal Display (LCD) projectors, autostereoscopic 3D displays and brightness enhancing reflective displays.

In each system, a micro-optic component such as a microlens array is aligned with at least one pixel of the spatial light modulator component. A possible system is shown in plan view in Fig. 1. A backlight 2 produces illumination 4 of an LCD input polariser 6. The light passes through a thin film transistor (TFT) substrate 8 and is incident on a pixel layer 10 comprising individually controllable phase modulating pixels 12-26. The pixels are arranged in rows and columns and comprise a pixel aperture 28 and a separating black mask 30. The light then passes through an LCD counter substrate 32 and a lens carrier substrate 36 upon which is formed a birefringent microlens array 38. The birefringent microlens array 38 comprises an isotropic lens microstructure 40 and an aligned birefringent material with an optical axis direction 42. The output of the birefringent lens then passes through a lens substrate 44 and a polarisation modifying device 46.

Each birefringent lens of the lens array is cylindrical; the lens array 38 is a lenticular screen and the geometrical axis of the lenses is out of the page. The pitch of the lenses in this example is arranged to be substantially twice the pitch of the pixels of the display such that a two view autostereoscopic display is produced.

In a first mode of operation, the polarisation modifying device 46 is configured

to transmit light with a polarisation state which is parallel to the ordinary axis of the birefringent material of the microlens array. The ordinary refractive index of the material (such as a liquid crystal material) is substantially matched to the index of the isotropic microstructure 40. Thus the lenses have no optical effect and there is
5 substantially no change to the directional distribution of the output of the display. In this mode, an observer will see all the pixels 12-26 of the display with each eye, and a 2D image will be produced.

In a second mode of operation, the polarisation modifying device 46 is configured to transmit light with a polarisation state which is parallel to the extra-
10 ordinary axis of the birefringent microlens array. The extraordinary refractive index of the material (such as a liquid crystal material) is different to the index of the isotropic microstructure 40. Thus the lenses have an optical effect and there is a change to the directional distribution of the output of the display. This directional distribution can be set as well known in the art so as an observer correctly positioned at the front of the
15 display will see a left image in their left eye corresponding to light from left image pixels 12,16,20,24 and in their right eye will see a right image corresponding to right image pixels 14,18,22,26. In this way, a switchable 2D to 3D autostereoscopic display can be produced.

Lens arrays are particularly suitable for autostereoscopic displays because they
20 combine the functionalities of high efficiency, small spot size and ability to manufacture using well known lithographic processing techniques.

It has been suggested to provide electrically switchable birefringent lenses for purposes of switching light directionally, for example to switch a display between a 2D mode of operation and a 3D mode of operation.

25 Electrically switchable birefringent liquid crystal microlenses are described in European Optical Society Topical Meetings Digest Series: 13, 15-16 May 1997 L.G. Commander et al "Electrode designs for tuneable microlenses" pp48-58.

In another type of switchable 2D-3D display [US6 069 650, WO 98/21620],

switchable microlenses comprising a lenticular screen filled with liquid crystal material are used to change the optical power of a lenticular screen.

In one form of the present invention, there is provided a display apparatus comprising:

- 5 an emissive spatial light modulator comprising an array of pixels of organic electroluminescent material each arranged to output substantially polarised light;
- a switchable polariser being switchable between a first and a second polarisation mode in which the polariser passes light of respective polarisation components; and
- a birefringent lens positioned to receive light from the spatial light modulator
- 10 arranged to direct light of a first polarisation component into a first directional distribution and to direct light of a second polarisation component into a second directional distribution different from the first directional distribution, the birefringent lens and the switchable polariser being positioned in series.

Polarised light from the spatial light modulator passes through the switchable

15 polariser and the birefringent lens (in either order). The mode of the polariser effectively selects light corresponding to one or other of the first polarisation component or the second polarisation component to be output from the display device. Accordingly, switching the mode of the polariser causes the light output from the display device to switch between the first and second directional distributions.

20 In many practical embodiments, the birefringent lens has substantially no effect on light of the second polarisation component so that the second directional distribution is the same as the directional distribution of the light input to the birefringent lens. This allows switching of the device between a mode in which the birefringent lens has no effect and a mode in which the birefringent lens modifies the directional distribution of

25 the display device.

The lens array may be used to modify the directional distribution of the display device, in one or both modes, to achieve a variety of different effects including, but not limited to, the provision of: a 3D autostereoscopic effect; regions of high brightness; or a

multi-user display system.

Thus such devices can be used for:

an autostereoscopic display means which can conveniently provide a moving full colour 3D stereoscopic image which may be viewed by the unaided eye in one mode of operation and a full resolution 2D image in a second mode of operation;

a switchable high brightness transfective and reflective display system which in a first mode may exhibit substantially non-directional brightness performance and in a second mode may exhibit substantially directional brightness performance; or

a multi-viewer display means which can conveniently provide one moving full colour 2D images to one observer and at least a second different 2D image to at least a second observer in one mode of operation and a full resolution 2D image seen by all observers in a second mode of operation.

In another form of the present invention, there is provided an optical apparatus comprising:

an emissive display light direction switching apparatus, comprising:
an emissive spatial light modulator apparatus comprising an array of emitting pixel regions each with a substantially polarised optical output;

a switchable polariser being switchable between a first polarisation mode that passes light of a first polarisation component and a second polarisation mode that passes light of a second polarisation component; and

a birefringent lens of a birefringence such that in operation the birefringent lens directs light of the first polarisation component substantially into a first directional distribution and light of the second polarisation component substantially into a second directional distribution different from the first directional distribution;

the switchable polariser and the birefringent lens being positioned in series and arranged such that, when input light comprising or resolvable into both the first and second polarisation components is input to the device, light output by the device is substantially of the first polarisation component and is substantially directed into the first directional

distribution when the switchable polariser is set to the first polarisation mode, whereas light output by the device is substantially of the second polarisation component and is substantially directed into the second directional distribution when the polariser is set to the second polarisation mode.

5 Preferably, one or more of the following optional features is present.

The emissive material may be a polymer electroluminescent material or a small molecule electroluminescent material.

The substantially polarised output may be:

a linear polarisation;
10 substantially the same direction for all of the pixels;
achieved by uniaxially aligned chromophores; and/or
aligned parallel to the geometric optical axis of the birefringent lens.

A clean-up polariser may be used. It may be positioned between the pixels of the emissive display and the other optical components. The clean-up polariser may have a
15 transmission axis which is substantially parallel to the major axis of the output polarisation of the emissive display.

The geometric optical axis of the lens may be aligned with the pixels of the spatial light modulator.

The pixels may be arranged in rows and columns.

20 The display apparatus may include any of the features of the display apparatuses disclosed in International Application No. PCT/GB02/003513, which is incorporated herein by reference, including all the features in the claims of International Application No. PCT/GB02/003513, with the change that the display apparatus has an emissive spatial light modulator comprising an array of pixels of organic electroluminescent
25 material each arranged to output substantially polarised light. The advantages of the display apparatuses disclosed in International Application No. PCT/GB02/003513 apply equally to the present invention.

Embodiments of the present invention can provide the following advantages,

singly or in combination:

A switchable directional display apparatus using an emissive display can be configured with high optical efficiency;

5 The apparatus allows efficient switching between a high resolution, high brightness 2D mode and a high brightness 3D mode;

The apparatus allows efficient switching between a standard brightness 2D mode and an enhanced brightness 2D mode, effectively increasing the optical aperture of the display;

10 The apparatus can be manufactured at low cost;

The optical cross talk of the 3D mode can be optimised;

The use of emissive display allows a thin device to be fabricated without the use of a backlight element;

The elements can be manufactured using known techniques;

The display can operate in a wide range of operating environments.

15 Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 shows a type of switchable 2D-3D autostereoscopic display apparatus using a liquid crystal display;

20 Fig.2 shows another type of switchable 2D-3D autostereoscopic display apparatus using a polarised emissive display;

Fig.3 shows the another type of switchable 2D-3D autostereoscopic display apparatus using a polarised emissive display;

Fig.4 shows another type of switchable 2D-3D autostereoscopic display apparatus using a polarised emissive display;

25 Emissive displays such as inorganic and organic electroluminescent displays including polymer and small molecule organic electroluminescent displays typically produce an unpolarised optical output. However, directional distribution optical switching systems may rely on polarisation switching in order to enable a display to be

reconfigured between a first mode which may be Lambertian for example, and a second mode which may be autostereoscopic 3D windows for example. Unpolarised displays will thus show a polarisation loss when combined with polarisation directional distribution optical switching systems.

5 It is the purpose of this invention to provide high optical efficiency in emissive displays by aligning the output polarisation of polarised emissive displays with the input polarisation state of directional distribution optical switching systems. The polarisation alignment may be achieved by means of uniaxial aligned chromophores of the emissive material in the emissive pixels of the display. The alignment direction of the major axis
10 of the polarisation output may be set to cooperate with the alignment directions of the birefringent material in a birefringent microlens.

In this way, a high efficiency emissive directional distribution optical switching display may be achieved. Such a display has additional advantages over LCD displays, for example not requiring a backlight and thus can be made thinner and lighter which
15 can be important for mobile applications.

Fig.2 shows a first embodiment of the present invention. An array of pixels 50 is formed on a display substrate 48. The substrate 48 may comprise an array of addressing thin film transistors and electrodes so that each of the pixels may be independently addressed with an electrical signal. The thin film transistors may be inorganic or may be
20 embodied in organic materials. Alternatively, the pixels may be addressed by a passive addressing scheme in which addressing transistors need not be present at the pixels. Each of the pixels 50 comprises an emissive region in which the emissive material comprising chromophores is uniaxially aligned so that the polarisation of emission is substantially linear and substantially in the same orientation for the entire pixel.
25 Preferably, each pixel is arranged to have substantially the same polarisation direction.

The emissive material may be any organic electroluminescent material, for example a polymer electroluminescent material or a small molecule electroluminescent material. The emissive material may be arranged to produce polarised emission by

aligning the molecules of the emitting material using any suitable technique. For example, the emissive material may be that disclosed in "Polarized Electroluminescence from an Anisotropic Nematic Network on a Non-contact Photoalignment Layer", A.E.A. Contoret, S.R. Farrar, P.O. Jackson, S. M. Khan, L. May, M. O'Neill, J.E. Nicholls, S.M. Kelly and G.J. Richards, Adv. Mater. 2000, 12, No. 13, July 5 p 971 which demonstrates that polarisation efficiencies of 11:1 can be achieved in practical systems.

A further cover substrate 52 is attached to the pixels. The substrate 52 may incorporate barrier layers and contrast enhancement black mask layers.

An optional polariser 54 may be attached to the substrate 52. Alternatively, polariser materials may be incorporated at or near to the pixel plane, on the inner surface of the substrate 52 for example.

For an example, one known polarised organic electroluminescent display has a polarisation ratio of 11:1. In combination with a typical polariser of polarisation efficiency 45%, the overall throughput from the light source will be 82.5%, compared to 45% for an unpolarised light source in combination with a clean-up polariser.

An optional substrate 56 is attached to the polariser 54, and has a birefringent microlens formed on its surface. The birefringent microlens incorporates a surface relief structure such as a lenticular surface relief structure. The surface relief structure may be formed at the interface of a birefringent material and an isotropic material. The birefringent microlens incorporates a birefringent material with alignment direction 42, and an isotropic material 40. The birefringent microlens may for example comprise an aligned liquid crystal material such as a nematic liquid crystal sandwiched between homogeneous alignment layers on substrate 56 and on the surface of the isotropic material. Homeotropic alignment layers may also be used. The birefringent material may be UV cured liquid crystal material such as a reactive mesogen liquid crystal. The relative alignment of liquid crystal material on the two surfaces of the birefringent lens may be parallel, anti-parallel, or there may be twist between the two surfaces so that an incident polarisation is rotated in the birefringent lens before encountering the surface

relief structure. The refractive index and dispersion of the isotropic material may be substantially the same as one of the refractive indices of the birefringent material. Embodiments of birefringent microlenses which are applicable to the present invention are described in International Application No. PCT/GB02/003513, which is incorporated
5 herein by reference.

Following the birefringent microlens, a polarisation switch cell is formed on a substrate 41. The switch serves to switch the polarisation transmitted through a final linear output polariser 66 and may comprise a layer of nematic liquid crystal material 60 sandwiched between transparent ITO electrodes and alignment layer 58. In order to
10 switch the output polarisation from the switch cell, a voltage 62 is applied across the liquid crystal cell.

The apparatus of Fig.2 operates in the following manner. The emissive display produces a substantially linearly polarised output polarisation. The output polarisation from the polarised emissive pixel array 50 is cleaned by the linear polariser 54 which has
15 a transmission direction parallel to the major axis of the polarisation direction of the emissive material. This polarisation state is aligned at 45 degrees to the alignment of the liquid crystal material in the birefringent lens 42, so that it is resolved in to two orthogonal components by the lens. The polarisation switching material 60 in a first state is aligned so that the polarisation state transmitted through the output polariser 66
20 is parallel to the normal refractive index of the liquid crystal material in the birefringent lens 42. This refractive index is substantially matched to the refractive index of the isotropic material 40, and thus there is substantially no lens effect, although there may be a small residual optical effect to the extent that it is not possible to obtain a precise refractive index match. The display then has a directional distribution which is
25 substantially the same as the optical output from the pixel plane.

In a second mode, the switch 62 adjusts the material 60 so that the transmitted polarisation through the polariser 66 has seen the extraordinary refractive index of the birefringent material 42 and thus there is an index step to the isotropic material at the

lens surface, and the lens has an optical function. This causes a change in the directional distribution of the optical output. The lens may be arranged to produce an image of the pixel plane at a window plane.

In this specification, the direction of the optical axis of the birefringent material (the director direction, or the extraordinary axis direction) will be referred to as the birefringent optical axis. This should not be confused with the optical axis of the lenses which is defined in the usual way by geometric optics.

The alignment of liquid crystal in the lens may be set to be parallel through the thickness of the cell. The alignment at the lens surface may be parallel to the geometric lens axis of the cylindrical lenses. Alternatively, the birefringent optical axis may be arranged to rotate through the cell so that the polarisation alignment direction of the emissive display and clean up polariser are at an angle different to the geometric lens axis. This may be advantageous for example to relax manufacturing tolerances in fabrication of the polarised emission devices, or to improve the viewing angle of the devices if there are restrictions placed on viewing angle by the polarised emission conditions.

The lenses may be arranged in columns with a pitch substantially (but not exactly) twice the pitch of the columns of pixels of the display. If a user places their eyes in the window plane, alternate columns of pixels of the panel may be seen, and a stereo image may be observed. This optical output is described in PCT/GB2002/003513.

Alternatively, the lens can be arranged as rows of cylindrical lenses with a pitch substantially the same (but not exactly) as the pitch of the rows of the display. If the aperture ratio of the pixels is less than 100% in the vertical direction, then in the directional mode of operation, the lenses will produce regions from which the display will have a higher brightness separated by regions of lower brightness due to the focussing of the lenses from the centre of the pixels.

The apparatus of Fig.2 has a nominal 50% brightness because the input

polarisation state to the lenses is resolved in to two orthogonal components respectively parallel and orthogonal to the birefringent optical axis of the birefringent microlenses.

An apparatus which can show a full brightness mode of operation is illustrated in Fig.3. Compared to Fig.2, the position of the polarisation switch and birefringent microlens array have been reversed. The output polarisation from the polarised emissive display and clean-up polariser 54 is incident on the polarisation switching mechanism 60,58,62. In a first mode, no polarisation switch takes place so that the polarisation incident on the birefringent microlens array 42 is parallel to the ordinary component of the refractive index at the lens surface, and substantially no lens is seen because of the index match to the isotropic material 40. The light passes through a final substrate 68 which may comprise for example anti-reflection films. Thus the light has substantially the same directional distribution as the emissive panel.

In the second mode of operation, the polarisation switch rotates the polarisation from the panel so that it is parallel to the birefringent optical axis of the birefringent microlens, and the lens has an optical function.

In this configuration, all of the light sees the correct lens axis and thus there are substantially no losses in the system.

Such a configuration has an increased viewing distance because of the thickness of the additional layers. The thickness can be reduced by removing the substrate 64 and using cured liquid crystal material for the birefringent lens, as shown in Fig.4. An optional substrate 70 is formed on the polariser 54 and has ITO and alignment layers 58 formed on its opposite surface. The birefringent microlens and isotropic material may be formed on a substrate 68 with an ITO coating 72. The birefringent microlens array 42 may be made from a UV cured material, such as a reactive mesogen, and an alignment layer 74 may be formed on its surface. A switchable polarisation modulating material such as a nematic liquid crystal 60 may be sandwiched between the microlens alignment layer 42 and the ITO and alignment layer 58. Alternatively, the ITO coating 72 may be formed on the UV cured birefringent microlens 42 surface in combination with the

alignment layer 74. A voltage is applied to the ITO coatings by an electrical source 62.

In this manner, the separation of the lens from the pixel plane may be reduced. This is particularly advantageous for devices with small pixel sizes. The substrate 70 may also be removed, so that the layers 58 are formed on the polariser 54 for example.

5 Fig. 5 shows a switchable enhanced brightness display apparatus using a polarised emissive display;

As shown in Fig. 5, the polarised emissive pixels in a pixel plane 50 may comprise emissive regions 80 and gaps 82 between the emissive pixels. The gap regions may comprise electrodes or addressing transistors for example. The lenses may be
10 positioned in rows with respect to the display. And the pitch of the lenses is set to be substantially the same as the pitch of the rows of the pixels. The remainder of the elements of the display may be configured and operate as in Fig. 4 for example. In a first mode of operation, the lens is configured to have no optical function so that the light from the emissive region is substantially unmodified by the lenses of the cylindrical
15 lens array. In a second mode of operation the lenses are configured to have an optical function so that each of the pixels is imaged by a respective lens to a window plane at a nominal distance from the display. If an observer places their eye at the image of the pixels at the window plane then the display will have an increased brightness compared to the unmodified display. If the observer places their eye at the gap between the
20 images, then the display will have a reduced brightness than the modified display. In this manner, the display brightness can advantageously be improved in cases where the aperture ratio of the pixel is less than 100% in a first direction.

Further embodiments of the present invention may be formed as the display apparatuses disclosed in International Application No. PCT/GB02/003513, which is
25 incorporated herein by reference, but replacing the spatial light modulators disclosed therein by an emissive spatial light modulator comprising an array of pixels of organic electroluminescent material each arranged to output substantially polarised light, as described above. Therefore the disclosure of International Application No.

PCT/GB02/003513 applies equally to the present invention except for the replacement of the spatial light modulator.

Claims

1. A display apparatus comprising:
 - an emissive spatial light modulator comprising an array of pixels of organic
 - 5 electroluminescent material each arranged to output substantially polarised light;
 - a switchable polariser being switchable between a first and a second polarisation mode in which the polariser passes light of respective polarisation components;
 - a birefringent lens positioned to receive light from the spatial light modulator arranged to direct light of a first polarisation component into a first directional
 - 10 distribution and to direct light of a second polarisation component into a second directional distribution different from the first directional distribution, the birefringent lens and the switchable polariser being positioned in series.

Abstract

DISPLAY APPARATUS

A display apparatus comprises: an emissive spatial light modulator comprising an array of pixels of organic electroluminescent material each arranged to output
5 substantially polarised light; a switchable polariser being switchable between a first and a second polarisation mode in which the polariser passes light of respective polarisation components; and a birefringent lens positioned to receive light from the spatial light modulator. The birefringent lens is arranged to direct light of a first polarisation component into a first directional distribution and to direct light of a second polarisation
10 component into a second directional distribution different from the first directional distribution, the birefringent lens and the switchable polariser being positioned in series.

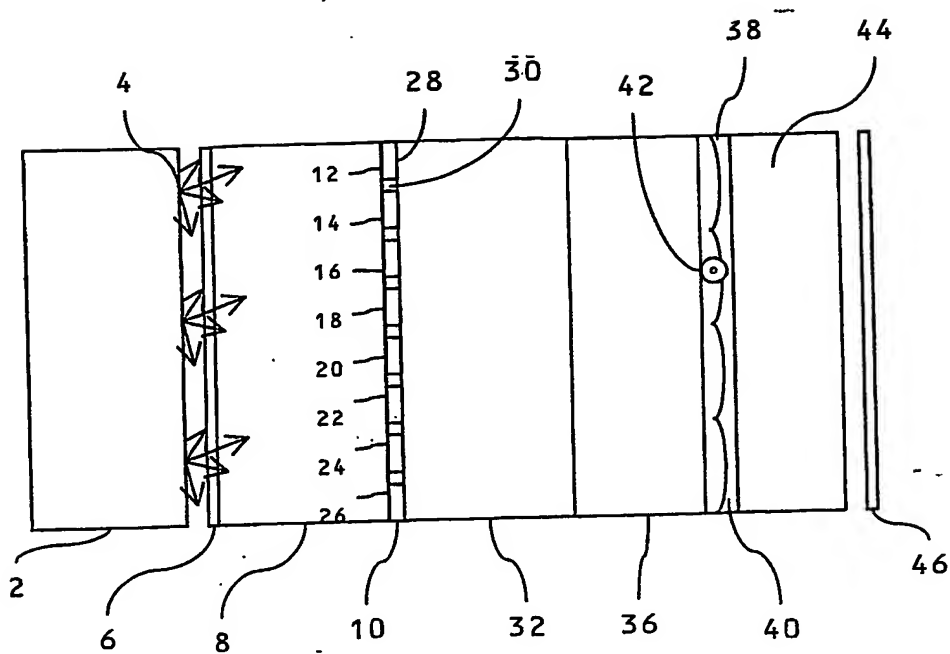


FIG. 1

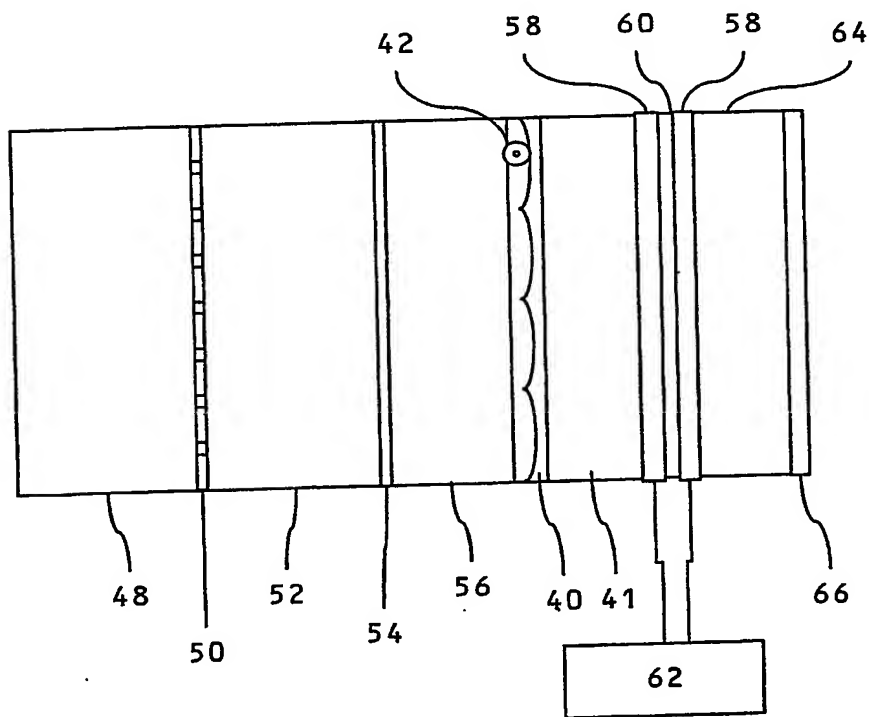


FIG. 2

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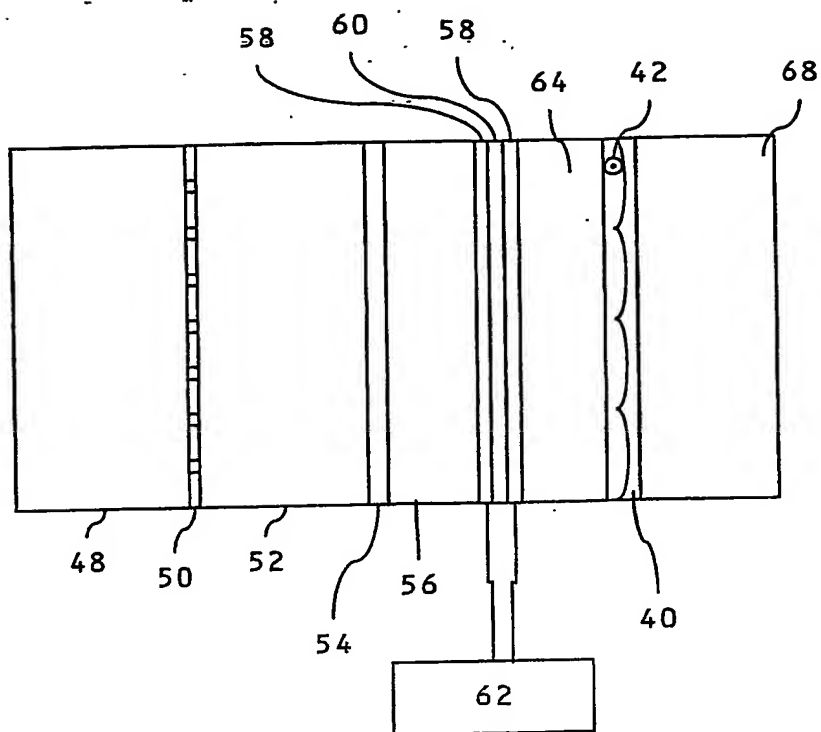


FIG. 3

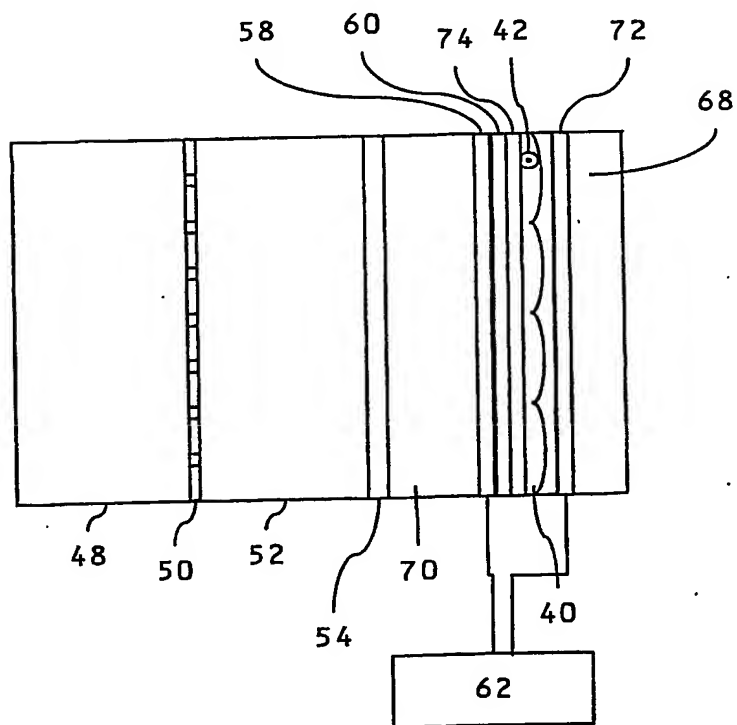


FIG. 4

3/3

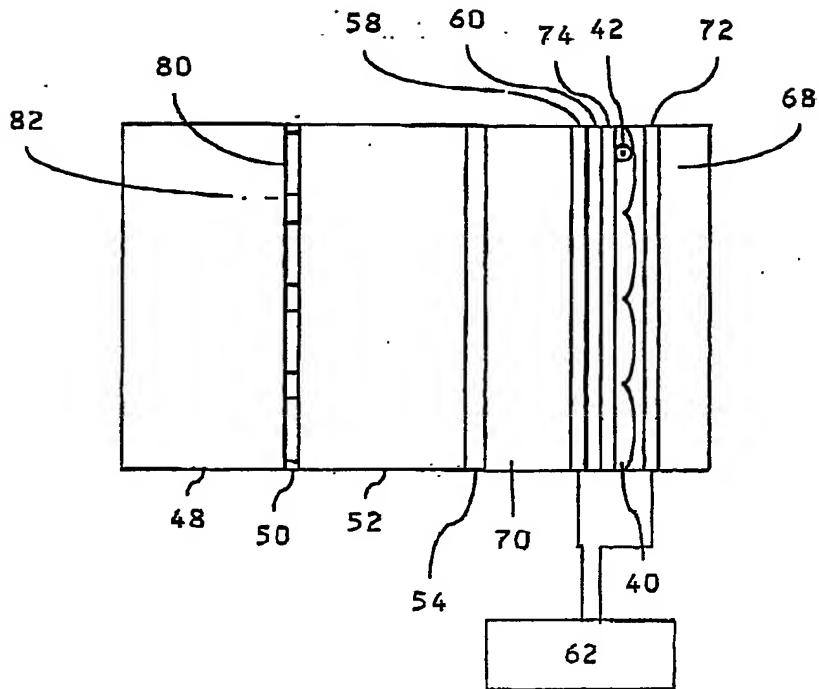


FIG. 5

PCT Application
PCT/GB2004/000366



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